AutoSplit Specification

for the

Concept Prototype

written by:

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Exhibit E

1.0 Purpose

This document defines the requirements for the AutoSplit concept prototype. The prototype will have restricted use as an engineering vehicle for feasibility and market evaluation.

1.1 Acronyms

ECM - engine's electronic control module
ECU2 - AutoSplit's electronic control unit

2.0 Applicable Documents

J1939 Recommended Practice for a Serial Control and Communications Vehicle Network (Class C)
J1939 Committee Draft; August 13, 1993
J1939/21 Data Link Layer; April 7, 1994
J1939/81 Network Management; April 8, 1994
J1939/11 Physical Layer; December 16, 1993
J1939/31 Network Layer; April 7, 1994
J1939/71 Application Layer, March 31, 1994
Patent disclosure XXXXXX submitted by T. Genise

3.0 Application

The concept AutoSplit system shall function exclusively with engines compatible with SAE J1939 and the Super10 Eaton Fuller Transmission. The Super 10 transmission provides for the following gear ratios:

Gear	Front Box Ratio	Rear Box Ratio	Overall Ratio
Reverse High	3.8897	2.3571	9.1686
Reverse Low	3.8897	3.1224	12.1454
First	3.1725	3.1224	9.9057
Second	3.1725	2.3571	7.4778
Third	1.7825	3.1224	5.5658
Fourth	1.7825	2.3571	4.2016
Fifth	1	3.1224	3.1224
Sixth	1	2.3571	2.3571
Seventh	1.7825	1	1.7825

Eighth	1.7825	0.7549	1.3456
Ninth	1	1	1
Tenth	1	0.7549	0.7549

The signals provided by the speed sensor will have the following calibrations:

Input Shaft Pulses: *31.3043* pulses per revolution of the input shaft
Rear Counter Shaft Pulses: *113.1429* pulses per revolution of the output shaft when the range is in low gear.
36.2353 pulses per revolution of the output shaft when the range is in high gear.
Output Shaft Pulses: *16* pulses per revolution of the drive shaft.

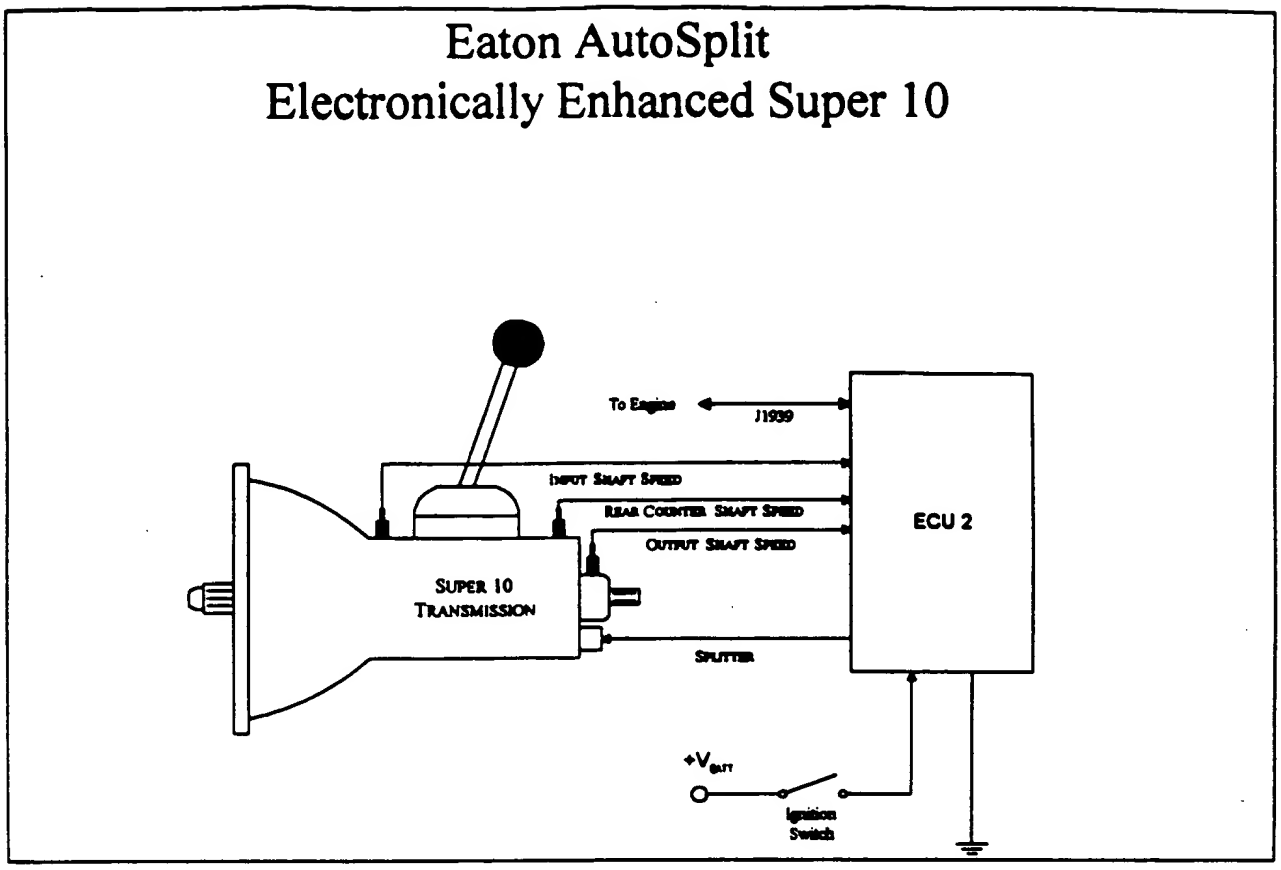
4.0 System Description

The AutoSplit system electronically enhances the operation of the Super10 transmission having the preponderant feature of eliminating the need for manual control of the spitter interface. The AutoSplit system fully automates the operation of the splitter, but retains the human interface between the driver and the main box transmission.

The AutoSplit system incorporates the following components in addition to the standard Super10 speed transmission:

1) Three speed senors
2) Two electric-pneumatic splitter solenoids
3) An electronic control unit which receives information from the speed sensors and controls the operation of the splitter actuator and provides control information to the engine via SAE J1939.
4) Wiring harness

A block diagram of the AutoSplit system is depicted in Figure 1.



4.1 System I/O

The concept AutoSplit prototype system will include the following inputs and outputs.

Development I/O

J1708/J1587 Panel Interface

Vehicle Inputs

Ignition Voltage

Inputs from Transmission

Input Shaft Pulses

Rear Counter Shaft Pulses

Output Shaft Pulses

Outputs to Transmission

Splitter Solenoid 1

Splitter Solenoid 2

Engine Inputs/Outputs

J1939 Inputs/Outputs

4.2 Vehicle Inputs

Ignition voltage is used to supply power to ECU2. When the ignition is switched to the "ON" position, ECU2 will be supplied with the vehicle's battery voltage, typically 12 volts. When the ignition is switched to the "OFF" position the vehicle battery voltage will be removed from ECU2.

4.3 Inputs from Transmission

Input Shaft Pulses are converted to input shaft speed. Input shaft speed (together with the output shaft speed) is used to determine whether the transmission is in gear or not. The input shaft speed is also used to determine the gear ratio (along with output shaft speed) when the transmission is in gear and the state of synchronous when the transmission is being shifted to a new gear.

Rear Counter Shaft Pulses are converted to rear counter shaft speed. Rear counter shaft speed is used to determine when the transmission range has synchronized during a compound shift. The rear counter shaft speed will also be used to calculate the transmission output shaft speed when the output shaft sensor is incapable of generating output shaft pulses.

Output Shaft Pulses are converted to output shaft speed. Output shaft speed (together with the input shaft speed) is used to determine whether the transmission is in gear or not. The output shaft speed is also used to determine the transmission gear ratio (along with input shaft speed) when the transmission is in gear. This signal is also a factor in determining shift schedules.

4.4 Outputs to Transmission

Splitter Solenoid 1 is a 12 volt, 2.5 amp electrical signal used to energize the solenoid that controls the direct gear of the splitter.

Splitter Solenoid 2 is a 12 volt, 2.5 amp electrical signal used to energize the solenoid that controls the overdrive gear of the splitter.

4.5 Engine I/O - refer to SAE J1939/71 for a definition of each of the following signals.

<u>Inputs from the Engine:</u>

Electronic Engine Controller #1: EEC1

Status_EEC1 - Engine/retarder torque mode

Drivers demand engine - percent torque

Actual engine - percent torque

Engine Speed
Electronic Engine Controller #2: EEC2
Accelerator pedal (AP) position
Percent load at current speed
Electronic Engine Controller #3: EEC3
Nominal friction - percent torque

Engine Configuration

Electronic Retarder Controller #1: ERC1
Status_ERC1 Engine/retarder torque mode
Retarder enable - brake assist switch
Retarder enable - shift assist switch

Cruise Control/Vehicle Speed
Measured_CC_SW1 Clutch Switch
Brake Switch

Outputs to the Engine
Torque/Speed Control #1: TSC1
Control bits Override control modes
Requested speed control conditions
Override control mode priority
Requested speed/Speed limit
Requested torque/Torque limit

Electronic Transmission Controller #1: ETC1
Status_ETC1 Driveline engaged
Shift in process
Output shaft speed
Command_ETC1 Momentary engine overspeed enable
Progressive shift disable

4.6 Development I/O

J1708/J1587 diagnostic port is used to communicate to a PC that contains PANEL. This serial communication link is used to collect data internal to the system and will be useful to expedite system and software development.

5.0 Functional Requirements

5.1 Power Up

The normal power up sequence shall be initiated when the ignition key is placed in the "ON" position. Vehicle conditions for normal power up are:

engine speed is zero, and
all transmission shaft speeds are zero, and
the vehicle is stopped, and
either the clutch is disengaged, and/or
the transmission main box is in neutral.

Powering the system up outside the above mentioned conditions is not recommended.

5.2 Power Down

The normal power down sequence shall be initiated when the ignition key is placed in the "OFF" position. Vehicle conditions for normal power down are:

output shaft speed is zero, and
rear counter shaft speed is zero, and
the vehicle is stopped, and
either the clutch is disengaged, and/or
the transmission main box is in neutral.

Powering the system down outside the above mentioned conditions is not recommended.

5.3 Vehicle Stopped

When the vehicle is stopped the system shall select the splitter direct ratio.

5.4 Reverse Operation

When the vehicle is operating in the reverse ratio the system shall select and maintain the splitter direct ratio.

5.5 Forward Operation

The system shall start any incipient forward movement of the vehicle in the splitter direct ratio. The driver may select any forward lever position of the front box transmission. All splitter shifts will be performed automatically by logic rules programmed into the software that resides in the AutoSplit ECU. The initiation of a splitter shift will be governed by shift rules also programmed in the ECU.

5.5.1 Neutral Detection

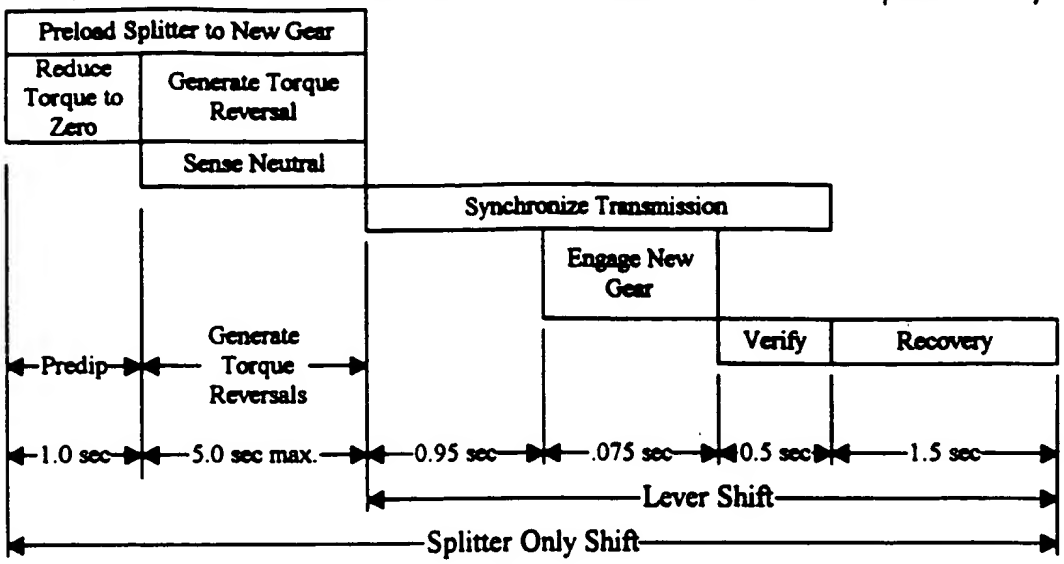
The AutoSplit will incorporate an algorithm that detects neutral by calculating the ratio between the input shaft speed and the output shaft speed of the transmission. If the ratio does not match any predefined ratios then neutral in the transmission will be declared.

5.5.2 Gear Engaged

The transmission will be considered engaged when the calculation of the ratio matches a valid predefined ratio for more than TBD (~0.5 seconds).

5.5.3 Shift Sequence Scenarios

During a shift event the AutoSplit system simultaneously controls the splitter actuator and the engine fueling. Control of the splitter and engine are addressed separately. The chart shown below depicts shift sequences with maximum times for both driver initiated shifts and splitter only shifts.



The ensuing subsections describe the individual sequences in more detail.

5.5.3.1 Splitter Control

Splitter Only Up-Shifts

The splitter will currently be in direct gear. When the shift is initiated split_hi is energized. When neutral in the splitter is sensed, the splitter solenoids are de-energized. When synchronous speed in the transmission is anticipated split_hi is re-energized. The split_hi solenoid will remain energized until gear_engaged is verified.

Splitter-Front Box Up-Shifts

The driver controls all front box shifts as he normally would for a standard manually operated Super10 transmission. The AutoSplit system senses a front box shift using the same algorithm used to detect neutral across the transmission.

The actual determination by the software algorithms of whether a driver-initiated shift is intended as an up-shift or down-shift is addressed in a later section of this document entitled "Shift Initiation".

In the case of an up-shift, the splitter will most likely be in overdrive gear. If in overdrive gear and when neutral is sensed, split_lo will be energized and remain energized until gear_engaged is verified. If in direct gear, the splitter will remain in direct but split_lo will be

energized and remain energized until gear_engaged is verified.

Splitter-Front Box-Range Up-Shifts

It is not necessary to distinguish between a compound front box-range-splitter upshift and a splitter- front box up-shift. A provision to monitor the rear counter shaft speed has been provided, thus allowing the system to determine when the range is synchronous. The RangeError would be calculated as follows:

$$RangeError = RCS - R_{ratio} X\ OS$$

where:

RCS = range counter shaft speed

OS = output shaft speed

R_{ratio} = 54/21 = 2.5714 for low split

= 42/51 = 0.8235 for high split

The same sequence as a splitter-front box up-shift will be used. It will be the responsibility of the driver to pause in front box neutral long enough for the range to synchronize. The system will protect the range by waiting for range synchronous before completing "sync mode".

Splitter Only Down-Shifts

The splitter will currently be in the overdrive gear. When the shift is initiated split_lo is energized. When neutral in the splitter is sensed, the splitter solenoids are de-energized. When synchronous speed in the transmission is anticipated split_lo is re-energized. The split_lo solenoid will remain energized until gear_engaged is verified.

Splitter-Front Box Down-Shifts

The driver controls all front box shifts as he normally would for a standard manually operated Super10 transmission. The AutoSplit system senses a front box shift using the same algorithm used to detect neutral across the transmission. In the case of a down-shift, the splitter will most likely be in direct gear. If in direct gear and when neutral is sensed, split_hi will be energized and remain energized until gear_engaged is verified. If in overdrive gear, the splitter will remain in overdrive but split_hi will be energized and remain energized until gear_engaged is verified.

Splitter-Front Box-Range Down-Shifts

A compound front box-splitter-range down-shift is similar to a splitter-front box shift. The same equation as defined previously would be used to

calculate the range error except the low ratio would be used for R_{ratio}.

The same sequence described under splitter-front box-range up-shift applies except if in direct gear and when neutral is sensed, split_hi will be energized and remain energized until gear_engaged is verified. If in overdrive gear, the splitter will remain in overdrive but split_hi will be energized and remain energized until gear_engaged is verified. It will be the responsibility of the driver to pause in front box neutral long enough for the range to synchronize. The system will protect the range by waiting for range synchronous before completing "sync mode".

5.5.4 Engine Control

The AutoSplit will control the engine via J1939 in four control modes defined as follows: 1) no override, 2) predip, 3) sync, and 4) recovery. The 4 modes are described below.

no override

In the no override engine control mode, the AutoSplit has no control over the engine. The engine, in this mode, follows the driver's throttle pedal or other engine imposed limits (i.e. cruise control, road speed governor, etc.).

predip

The predip mode applies only to splitter only shifts and is entered on the onset of the shift. The purpose of this mode is to induce a driveline torque reversal to allow the splitter gear to disengage. On the onset of a shift, the driveline torque could be positive, negative, or zero. If the torque is positive, the AutoSplit algorithm will gradually decrease fuel to provide a smooth transition from a positive torque to zero torque. If the torque is negative, the AutoSplit will command the engine to re-fuel in order to induce zero torque. If the driveline is at zero torque, no action is necessary and the splitter gear should disengage. If the first attempt to reverse the driveline torque is unsuccessful in disengaging the splitter, the AutoSplit system will cycle the engine between boost (re-fuel) and dip (no fuel) for a period not to exceed 5 seconds. The cycle pattern will be taken directly from the AutoSplit predip algorithm. Predip terminates when neutral is sensed or the shift is aborted after the 5 second attempt to disengage the gear.

sync

The sync mode is entered when neutral is sensed in the transmission. The AutoSplit system commands the engine into the speed control mode and provides a reference speed. The reference speed is based on the product of the current transmission output shaft speed and the newly selected gear ratio plus an offset speed. The purpose of the offset speed is to prevent gear butting due to near perfect matching of speeds across

the newly selected gears. The AutoSplit system will only allow an engine boost operation (fueling) for no more than 3 seconds unless the driver has depressed the throttle pedal greater than 3%. An engine boost will terminate when the system verifies that the transmission has engaged in the selected gear.

Recovery

The recovery mode is entered after gear engagement is verified and sync mode terminates. The purpose of this mode is to smoothly re-establish driveline torque. The AutoSplit recovery algorithm will gradually re-fuel the engine until the desired torque matches the torque requested by the driver via his pedal position or the engine's cruise control torque demand. The recovery logic and algorithms currently implemented in the AutoShift system will be used for the AutoSplit. If operating in the recovery mode and neutral is sensed in the transmission, the AutoSplit will revert back to the sync mode. This may occur because the driver initiated a front box shift or the splitter popped out of gear. The algorithm to termination this mode will come directly from the AutoSelect software.

5.5.5 Shift Initiation

There are two types of shift initiations: 1) fully automatic, splitter only shifts and 2) driver initiated, electronically assisted, front box shifts.

Splitter only shifts

The shift will be initiated based on a compromise between vehicle performance and fuel economy. Throttle modulated shift decision algorithms similar to those employed on AutoSelect and AutoShift will be used. Since the initial configuration will have no provisions to increase the deceleration of the input shaft, an algorithm that determines the feasibility and/or desirability to shift to another gear will be used. This algorithm will influence the shift decision and will be nearly identical to the shiftability algorithm used for AutoShift, but without the option of actuating an engine or input brake.

Driver initiated shifts

A driver initiated shift commences when the driver de-fuels the engine and manually shifts the transmission to neutral. A new gear is selected when the system detects neutral. When the new gear is selected, the system energizes the appropriate solenoid commensurate with the shift type, split_hi for an up-shift or split_lo for a down-shift. Simultaneously, the AutoSplit commands the engine to the speed override mode and provides it with a target speed. The algorithm for selecting the appropriate gear will be better defined during the development of the AutoSplit.

Initial development for selecting the "best gear" for lever assisted shifts will utilize the AutoSelect shift decision algorithms. If appropriate these algorithms will be modified in order to provide the correct gear selection decision.

5.5.6 Abnormal Operation

The concept prototype system will use whatever failsafe measures are provided by the AutoShift software. As stated above, the AutoSplit system will only command to override driver or engine imposed limits for 3 seconds or less, unless the driver depresses the throttle pedal greater than 3%.

The concept prototype system will have no fault detection or fault tolerance. In the event of a loss of engine communications, loss of electrical power, input shaft, or output shaft speed sensor failures, the splitter will remain it its current position. Provided that the splitter is not stuck in neutral, the driver retains to ability to shift the front box and operate the transmission as a 5 speed.

The concept prototype system will not monitor any of the I/O components for open or short circuits. It is expected that the ECU has been designed to sustain indefinite opens or shorts circuits without permanent damage to the ECU.

6.0 Electrical Requirements

6.1 Connector Requirements

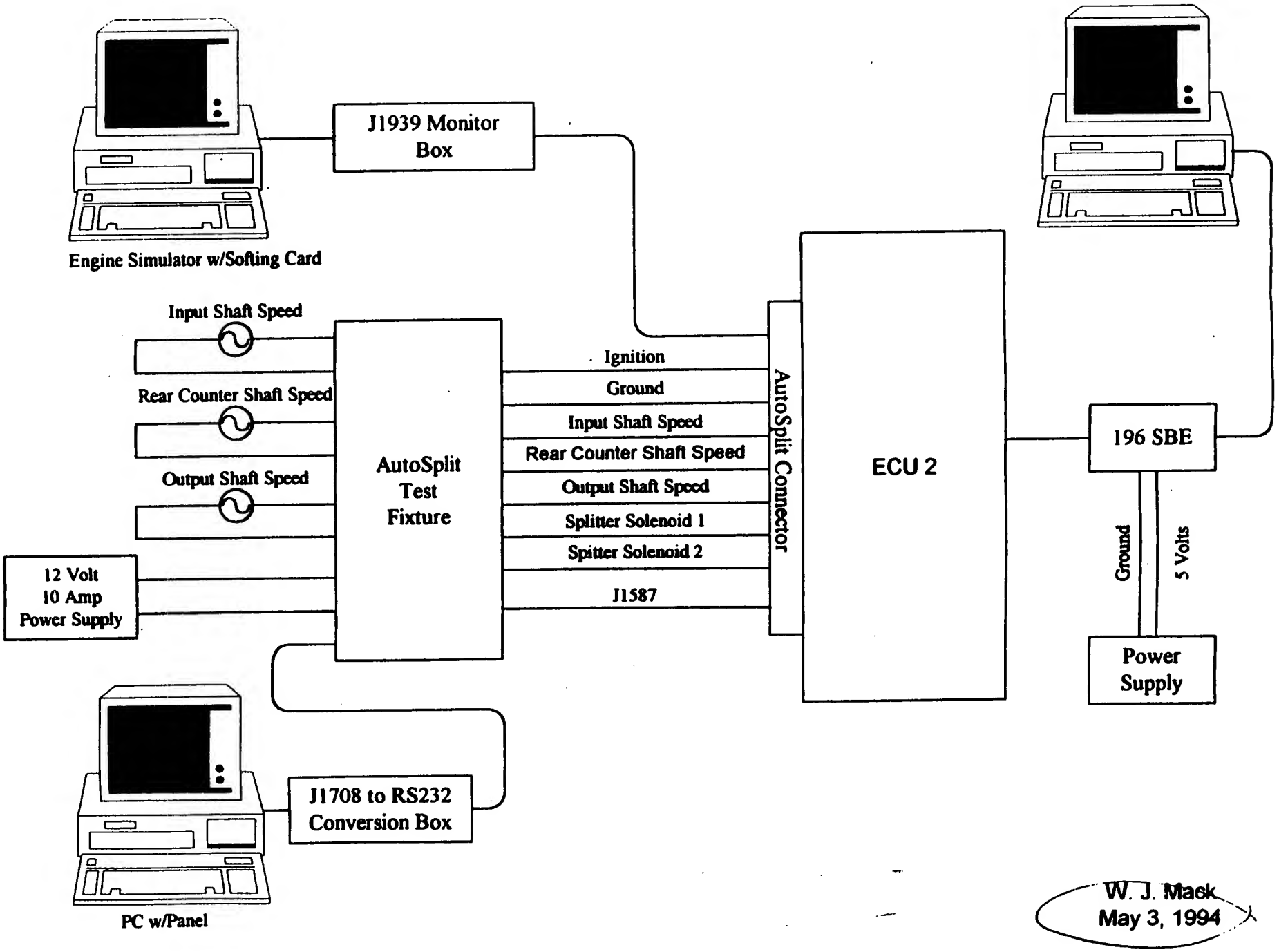
The concept AutoSplit system will use the ECU2 connector. The connector pin assignments can be found in Appendix A.

6.2 Splitter Solenoid 1, called split_lo, will control the solenoid that engages the splitter in direct gear. Splitter Solenoid 2, called split_hi, will control the solenoid that engages the splitter in the overdrive gear.

Appendix A - Connector Pin Assignments

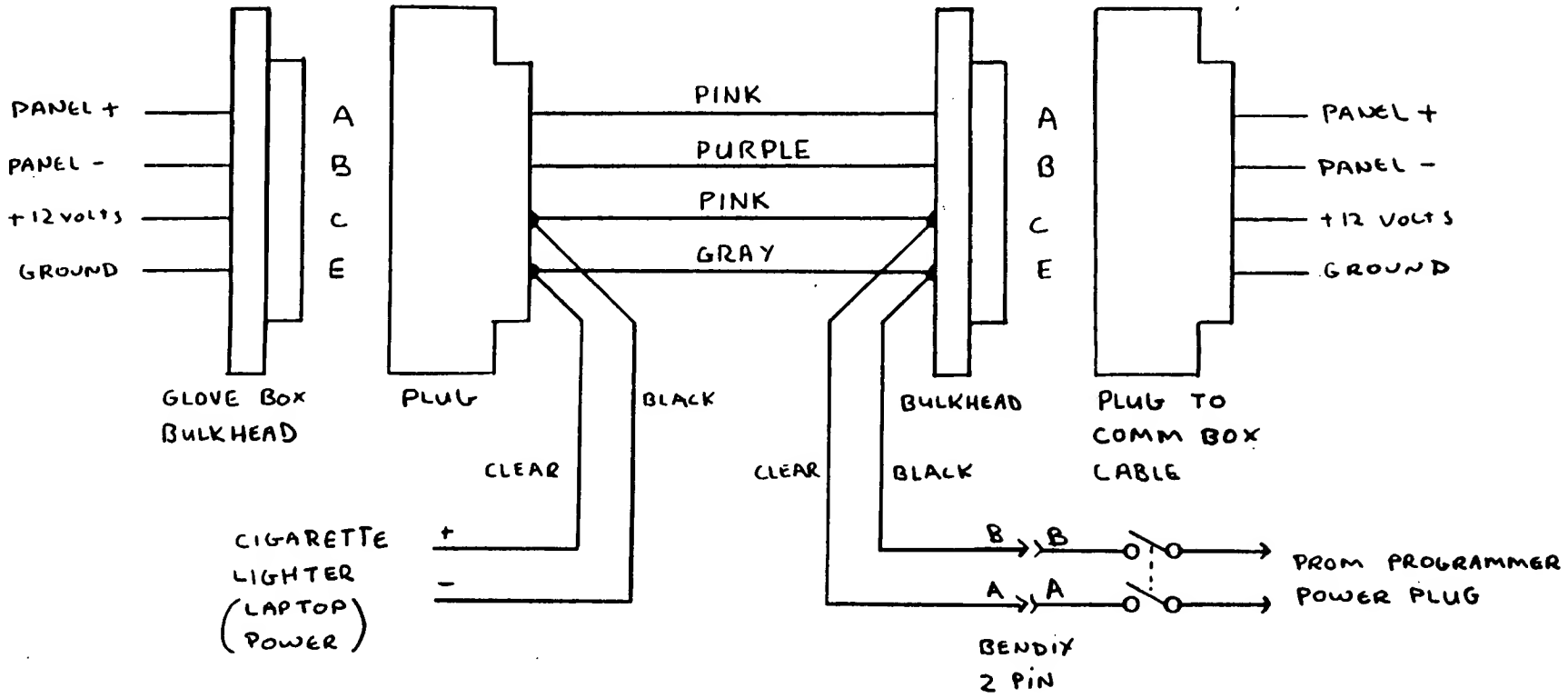
A1 - OS+	A2 - Not Used	A3 - Ground
B1 - OS-	B2 - Not Used	B3 - Ground
C1 - Inertia Brake	C2 - Not Used	C3 - Not Used
D1 - Not Used	D2 - Not Used	D3 - J1587+
E1 - Not Used	E2 - Splitter Solenoid 1	E3 - J1587-
F1 - Not Used	F2 - Not Used	F3 - Splitter Solenoid 2
G1 - Ignition	G2 - Not Used	G3 - RCS+
H1 - Not Used	H2 - Not Used	H3 - RCS-
J1 - Not Used	J2 - Not Used	J3 - IS+
K1 - Alive Light	K2 - Not Used	K3 - IS-
L1 - Not Used	L2 - Not Used	L3 - Not Used
M1 - Not Used	M2 - J1939+	M3 - Not Used
N1 - J1939 Shield	N2 - J1939-	N3 - Not Used
P1 - Not Used	P2 - Not Used	P3 - Not Used
R1 - Not Used	R2 - Not Used	R3 - Not Used
S1 - Not Used	S2 - Not Used	S3 - Not Used

AutoSplit Bench Setup



W. J. Mack
May 3, 1994

AUTOSPLIT POWER INTERFACE TO LAPTOP & PROGRAMMER



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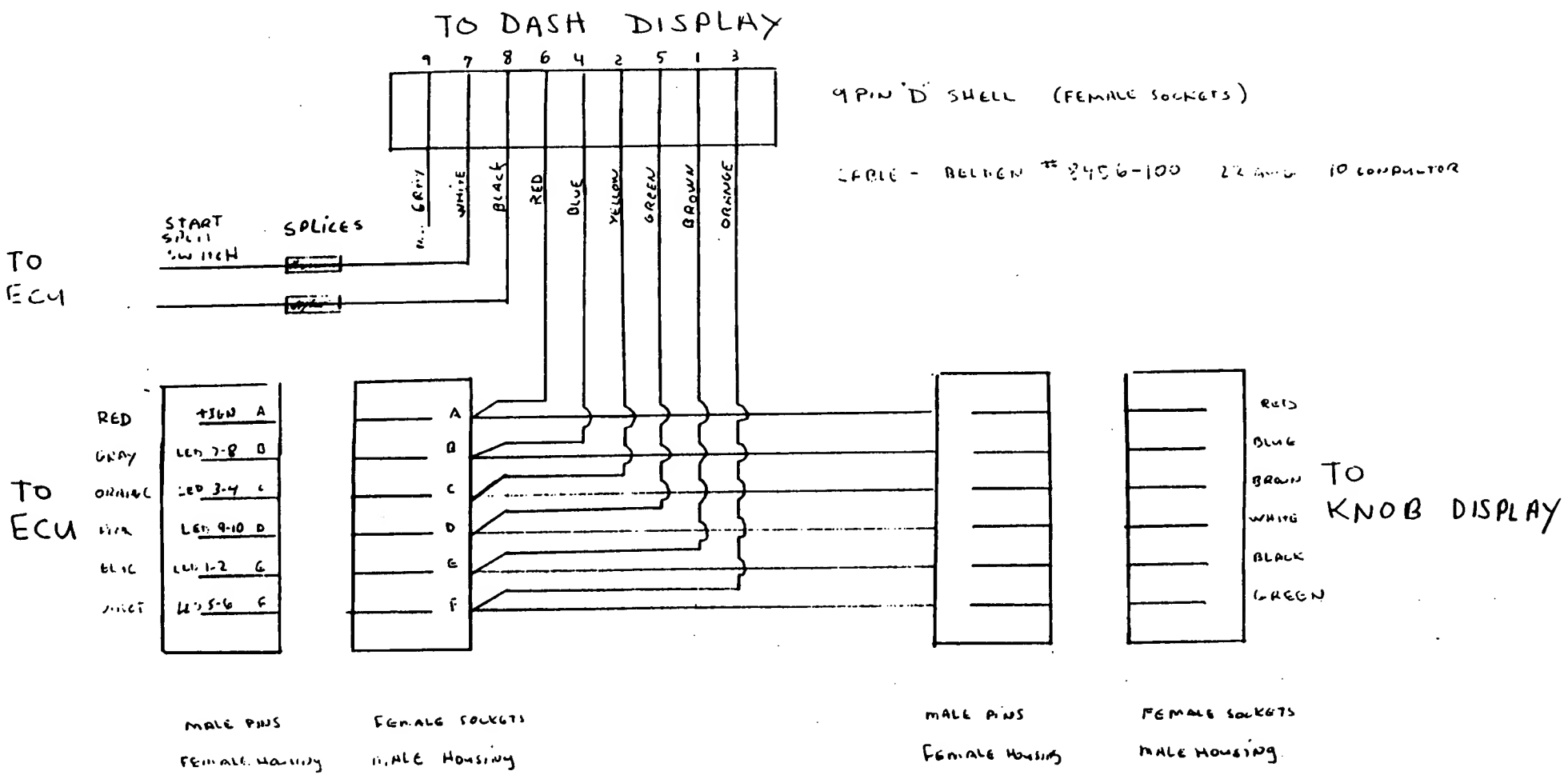
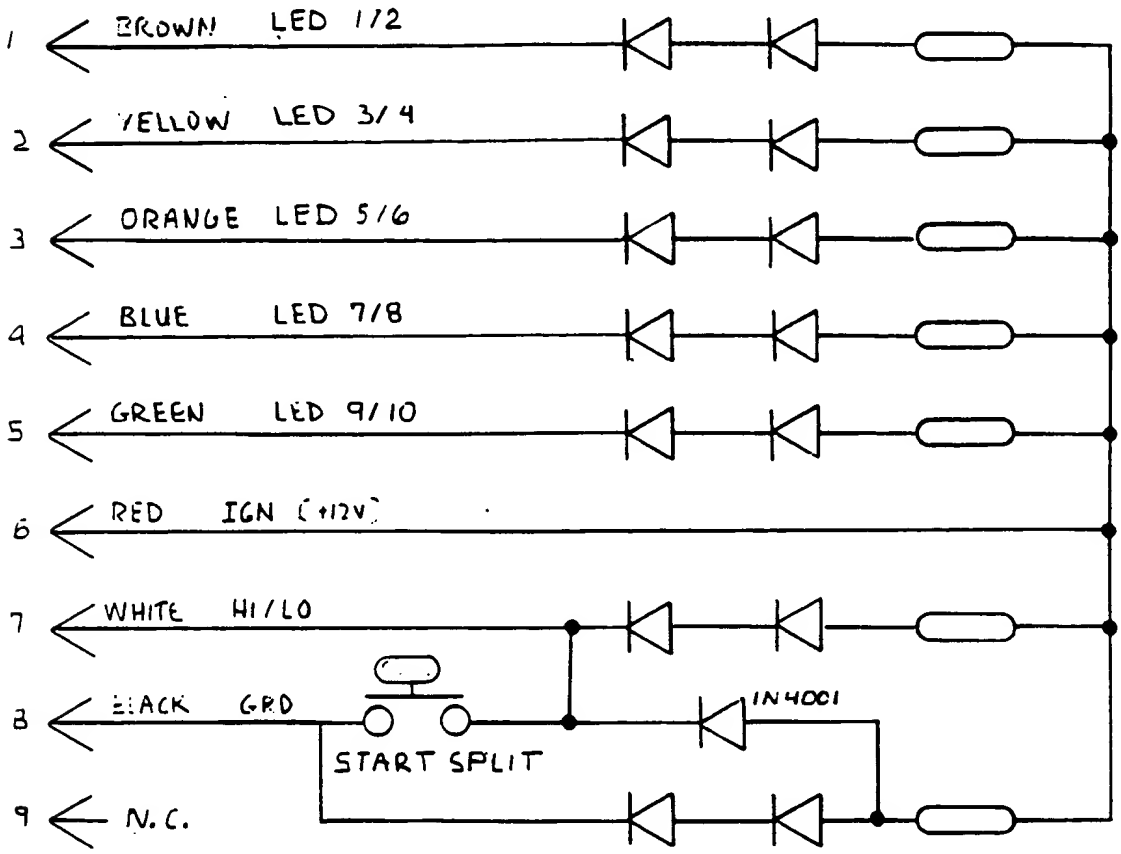


AUTOSPLIT
DASH DISPLAY HARNESS
9-7-94
R. K. MARKYVECH

AUTOSPLIT DASH MOUNTED GEAR DISPLAY



470Ω RESISTORS

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